Report on the Preferred Treatment Plan for EBR-II Sodium-Bonded Spent Nuclear Fuel

Prepared by the

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TABLE OF CONTENTS

Page Number

ACRONYMS AND ABBREVIATIONS

ACP	Actinide Crystallization Process
ANL	Argonne National Laboratory
ANL-W	Argonne National Laboratory – West
DOE	Department of Energy
EBR-II	Experimental Breeder Reactor-II
FCF	Fuel Conditioning Facility
HLW	High Level Waste
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho National Technology and Engineering Center
MEDEC	Melt Drain Evaporate Carbonate
MTHM	Metric Tons Heavy Metal
SMSW	Sodium Melt Solvent Wash
UREX+	Uranium Extraction Plus

LIST OF FIGURES

LIST OF TABLES

Executive Summary

As of Fiscal Year (FY) 2003, DOE is storing approximately 23 metric tons of EBR-II sodium-bonded spent nuclear fuel that has been identified for treatment. Sodium-bonded fuel contains elemental sodium, which is highly reactive to both air and water. As a result, final disposition cannot be accomplished until the fuel has been treated to remove this hazard.

With the requirement to have all spent nuclear fuel, including the EBR-II fuel, removed from Idaho by 2035, the Spent Fuel Treatment (SFT) plan was originally designed to complete the treatment of the sodium-bonded fuel using a technology called pyroprocessing. Pyroprocessing remains at the core of the Department's baseline plan to treat the EBR-II fuel. The treatment of this sodium-bonded fuel in Idaho will be focused on the roughly 3 metric tons of driver fuel that requires pyroprocessing since it has become infused with sodium. The pyroprocessing treatment of the driver fuel is expected to be completed in Fiscal Year 2017. Once the driver fuel treatment has been completed, the treatment of the approximately 20 metric tons of blanket fuel will begin and will take nearly 13 years to complete. The estimated total cost for the baseline SFT plan is approximately $657 million in unescalated Fiscal Year 2003 dollars. This estimate includes $115 million already spent between Fiscal Years 2000 and 2003, $282 million to be funded between Fiscal Years 2004 and 2017 for the treatment of the driver fuel, and $260 million to be funded between Fiscal Year 2018 and 2031 for the treatment of the blanket fuel.

In FY 2003, DOE combined the SFT program with the Advanced Fuel Cycle Initiative (AFCI) in order to benefit from the organizational efficiency and the inherent technological synergy between the two programs.

By combining the two programs, enhanced treatment rates for the EBR-II fuel may be realized through the development of a high throughput uranium electrorefiner that could increase capacity by almost 50% over current operations. This advancement has the potential to significantly improve the cost and schedule for the pyroprocessing treatment. In addition, the AFCI program is researching other spent fuel treatment alternatives, including Actinide Crystallization Process (ACP) and Uranium Extraction Plus (UREX+). These advanced fuel treatment processes along with other potential research areas could prove beneficial to treating the blanket fuel with significantly greater efficiencies than pyroprocessing operations alone. An initial analysis shows that these alternative treatment technologies could save up to six years off of the baseline schedule and reduce the cost for treating the EBR-II blanket fuel by hundreds of millions of dollars.

Through the combination of the strengths of current pyroprocessing and promising research activities, a relatively lower cost alternative for treating the EBR-II fuel may be possible. Under this hybrid approach, the driver fuel will be processed using existing pyroprocessing technology between now and fiscal year 2017. The Department will perform research and development on alternative treatment technologies as part of the AFCI program while the driver fuel is being treated. By the time this treatment is completed, the technology development from the on-going research within the AFCI program will be at a sufficient level of maturity to impact a decision on whether to continue with pyroprocessing treatment or begin using other treatment alternatives for the remaining blanket fuel.

In conclusion, the Department will meet the requirements of removing the EBR-II sodium-bonded spent nuclear fuel from Idaho by 2035. In doing so, the Department will utilize an approach that is technically sound, least expensive and most time effective.

1.0 Introduction

This report has been prepared by the Department of Energy (DOE) in response to the request of the House of Representatives' Appropriations Subcommittee on Energy and Water Development (House Report 107-681). This report will show how DOE intends to meet the agreement (Settlement and Consent order issued on October 17, 1995, in the actions of *Public Service Co. of Colorado v. Batt*, No. CV 91-0035-S-EJL [D. Id.] and *United States v. Batt*, No. CV 91-0054-EJL [D. Id]) to remove the EBR-II sodium-bonded spent nuclear fuel, currently stored in Idaho, from the state by 2035. The Department's baseline treatment program using current pyroprocessing technology will meet the 2035 date. However, significant cost and schedule benefits could be achieved if new technologies being developed as part of the Advanced Fuel Cycle Initiative (AFCI) prove successful and are applied to the treatment of the EBR-II sodium-bonded spent nuclear fuel.

2.0 Background

The Experimental Breeder Reactor (EBR-II) was operated in the State of Idaho from 1961 through 1994. The original purpose of the reactor was to demonstrate a complete breeder reactor power plant with on-site reprocessing of metallic fuels. Once this demonstration was completed, the reactor was reconfigured to be a burner reactor. Starting in 1969-1970, the burner reactor was used to test fuels and materials for other liquid metal reactors and at the end of its lifetime was used as the prototype for the Integral Fast Reactor (IFR).

The EBR-II in Idaho used sodium-bonded nuclear fuel elements. These fuel elements (Figure 1) have at their core a nuclear fuel rod that is bonded to the container with metallic sodium. Elemental sodium is a highly reactive metal, having exothermic chemical reactions with both oxygen (O_2) and water (H_2O) molecules that could eventually penetrate long-term storage containers. The situation is exacerbated by the fact that the reaction of sodium metal with water also produces dihydrogen (H_2), an explosive gas, and sodium hydroxide (NaOH), a corrosive base. In order to treat spent fuel of this type, the sodium must first be converted in a safe and controlled manner to a more stable oxidized form, such as table salt (NaCl).

At the closure of the EBR-II, 25.52 metric tons heavy metal (MTHM) of sodium-bonded spent nuclear fuel had been produced and stored on the Department's Idaho Site (Table 1). It should be noted that all of the spent fuel listed is currently located at ANL-W with the exception of 2.0 MTHM, which is stored at Idaho Nuclear Technology and Engineering Center (INTEC). The EBR-II sodium-bonded spent nuclear fuel has two primary categorizations – driver and blanket fuel. Driver fuel is highly enriched in the uranium-235 isotope and is the fuel that drives the fission chain reaction. Blanket fuel contains mostly non-fissile uranium-238, which converts into plutonium isotopes by capturing neutrons from the reactor.

The differentiation of these categories is important because each has a different isotopic profile that, in turn, affects how safe and efficient processing can be accomplished. For example, compared to blanket fuel, driver fuel has a larger quantity of fissile material, which limits the quantity of spent fuel that can be safely treated at any one time. Therefore, a process to remove the sodium must be used that keeps the fuel in a criticality-safe geometry, quantity and chemical form.

The other key difference between driver and blanket fuel is the interaction of the sodium with the metallic fuel rod. Within the reactor, the driver fuel assemblies were placed at the core while the blanket assemblies were positioned at the periphery. As a result of this physical placement, the driver fuel encountered extreme thermal and radiation conditions, causing the fuel rod to swell. The swelling forced the sodium to become infused with the metallic fuel rod. As a result of this infusion, the only viable mechanism to separate the sodium from spent driver fuel is through chemical means. The blanket fuel on the other hand experienced little to no swelling, since its environmental conditions within the reactor were significantly less severe. This lack of swelling resulted in the sodium remaining merely physically bound to the surface of the blanket fuel rod, allowing either chemical or physical methods to be viable paths for the sodium removal.

With the constraints of the isotopic contents and the different interactions of the metallic sodium with the fuel, the Department decided to use chemical methods as the mechanism to remove the sodium from both the driver and blanket fuel rods. In Fiscal Year 2000, the Department implemented the Spent Fuel Treatment (SFT) program in order to safely remove the metallic sodium from the fuel using an electrometallurgical treatment technology called pyroprocessing. Prior to the inception of the SFT program, an Environmental Impact Statement as well as a Record of Decision for the treatment of the EBR-II with pyroprocessing was attained.

Developed by Argonne National Laboratory (ANL), pyroprocessing accomplishes the separation of spent nuclear fuel using electrolytic methods. The current baseline pyroprocessing method (Figure 2) uses high temperature molten salts, *e.g.*, lithium chloride/potassium chloride (LiCl/KCl), and steel electrodes. Once dissolved in the high temperature melt, the metals in the fuel rod are oxidized to chloride complexes, e.g. table salt (NaCl), uranium trichloride (UCl_3), *etc.* During the electrometallurgical process, highly reactive metals such as uranium (U) are selectively deposited on the electrodes from the high temperature melt when voltage is applied. An inert atmosphere in the pyroprocessing hot cell is maintained throughout the entire procedure, since the resulting metals can react vigorously with air and water. While the corrosive properties of the molten salts and the inert atmosphere technology require expensive equipment that can elevate the costs, pyroprocessing has the distinct advantage of an excellent criticality safety profile and proliferation-resistance. The latter benefit is achieved since the plutonium contained in the spent fuel is never separated from the other actinides and is therefore unsuitable for nuclear weapons production.

During the demonstration phase of the pyroprocessing technology, the Department treated 0.410 MTHM of driver fuel and 0.620 MTHM of blanket fuel. Since the inception of the SFT program in FY 2000, the Department has treated an additional 0.048 MTHM and 1.585 MTHM of EBR-II driver and blanket fuel, respectively. The cost associated with treating the fuel through Fiscal Year 2003 is approximately $115 million. The baseline plan discussed in this report represents a realignment of the schedule detailed in the initial SFT program plan that was backed by the Record of Decision. As such, the pyroprocessing of the remaining EBR-II fuel is not a new program and the new baseline represents a continuation of the current program with greater focus on full-scale fuel treatment and enhanced throughputs as a result of research and development activities over the past three years. Table 1 summarizes the amount of the EBR-II sodium-bonded spent nuclear fuel that has been treated to date and also the amount that remains to be treated.

In Fiscal Year 2003, the Department merged the SFT program with the AFCI program to benefit from the organizational efficiency and the inherent technological synergy between the two programs. The AFCI program is engaged in research and development activities that are designed to help meet the needs for sustainable nuclear energy by optimizing or closing fuel cycles. As part of this program, spent fuel treatment technologies are being developed that could optimize the utilization of Yucca Mountain and help avoid the need for a second repository. In addition, fuel-recycling capabilities are being sought to support the next generation of nuclear reactors (Generation IV) that could be used for either hydrogen production or actinide burning. These new reactors and fuel could reduce the radiotoxicity of spent nuclear fuel and reduce the half lives of the radioactive waste going to the repository from thousands of years to hundreds of years. The two most viable areas to address the needs for spent fuel treatment are pyroprocessing and aqueous-based processing. As a result, the AFCI program is attempting to develop and demonstrate advanced separations with pyroprocessing, Actinide Crystallization Process (ACP), and Uranium Extraction Plus (UREX+). The technical descriptions for these processes can be found in Section 4.

3.0 Preferred Treatment Plan

In preparing this report, the Department analyzed five primary alternatives, including a baseline using only pyroprocessing with minimal improvements, high throughput pyroprocessing, and a hybrid approach using pyroprocessing (Figure 2) and a newly developed technology. The different options were examined with the effect on the time to complete the removal of the EBR-II sodium-bonded spent nuclear fuel and the total cost for treatment. Within each of the scenarios, the impacts of different work schedules were also examined. The preferred plan was developed based on which option could lead to the quickest and least expensive treatment alternative given a normal work schedule, *i.e.* five days per week with a single eight-hour shift for the pyroprocessing operations. The normal work schedule provision was considered so as to eliminate the need for additional staff.

After a detailed analysis of the five scenarios discussed above, the least costly and most time efficient alternative was determined to be a hybrid. The highly enriched EBR-II spent driver fuel will be processed first, using the existing pyroprocessing capabilities of the Fuel Conditioning Facility (FCF) at ANL-W. The full-scale pyroprocessing treatment of the EBR-II spent blanket fuel will commence once the driver fuel is finished. This approach will allow the Department the time needed to obtain data from the research and development activities of the AFCI on alternative processes, e.g., ACP, UREX+, and direct metal oxidation. Should one of these alternatives lead to improvements in cost and schedule for the blanket fuel treatment, a substitution will be made for the baseline pyroprocessing of the blanket fuel.

3.1 Driver Fuel

A pyroprocessing treatment campaign focused on the EBR-II driver fuel can treat approximately 0.2 MTHM of driver fuel annually with a normal eight hours per day, five days per week operations schedule. At this rate, the remaining 2.7 MTHM of driver fuel could be safely treated in the existing pyroprocessing equipment by the end of 2017 with subsequent waste operations extending the full completion date to 2018. The EBR-II driver fuel has a significantly large quantity of fissile material that limits the throughput possible with the current pyroprocessing equipment. The AFCI program is investigating a number of technological improvements that in time should increase the treatment rates. It should be noted that during the treatment of the driver fuel, a small amount of blanket fuel would also be processed in order to blend down the highly enriched uranium metal to below 20% enrichment. The amount of blanket fuel required for blend down will be dictated by the availability of other sources of depleted uranium and could range from 0 to greater than 0.6 MTHM per year. As a result of this unknown, a representative quantity, 0.05 MTHM, of blanket fuel has been included in the schedule during each year of the driver fuel treatment.

The pyroprocessing operations for fiscal year 2003 are budgeted at nearly $20 million with a facility running on a normal operations schedule, *i.e.* eight hours per day, five days per week. Using this number as a basis, the total cost to process the remaining 2.7 MTHM of EBR-II driver fuel is estimated at $282 million using unescalated Fiscal Year 2003 costs.

3.2 Blanket Fuel

Approximately 2.2 MTHM (10% of the total blanket fuel inventory) of the EBR-II blanket fuel has been treated during the initial testing and demonstration of the pyroprocessing technology. Under the preferred treatment plan, the full-scale treatment of the blanket fuel (approximately 20 MTHM) will begin following the completion of the EBR-II driver fuel treatment activity. During the treatment of the EBR-II driver fuel, the remaining research and testing needed to complete the development and installation of a higher throughput electrorefiner to treat EBR-II blanket fuel will be accomplished. The higher throughput electrorefiner will allow for larger quantities of the low-enriched blanket fuel to be treated in a shorter time period over the existing pyroprocessing equipment. The additional funding required to complete and deploy the higher throughput electrorefiner is estimated at $1.5 million and has been included in the overall costs for this plan.

A pyroprocessing treatment campaign focused on the EBR-II blanket fuel and incorporating the higher throughput electrorefiner can annually treat approximately 1.5 MTHM of blanket fuel with a normal eight hours per day, five days per week operations schedule. At this rate, the treatment of the blanket fuel will take eleven years to complete using the pyroprocessing technology. An additional year is required to complete the waste treatment activities. As a result, full scale-treatment of the blanket fuel will be performed from Fiscal Year 2017 through Fiscal Year 2030. The costs associated with treating the blanket fuel and the additional year of waste treatment are estimated to be approximately $260 million in unescalated Fiscal Year 2003 dollars.

Figure 3 shows a graph of the total inventory of untreated EBR-II sodium-bonded spent driver fuel and blanket fuel as a function of time. The total cost for the pyroprocessing operations as a function of time is also shown in Figure 3.

This pyroprocessing baseline for the full-scale treatment of the EBR-II sodium-bonded spent nuclear fuel is an expensive and time-consuming effort. However, during treatment of the EBR-II driver fuel, other alternatives currently being researched as part of the AFCI program will be examined for application to the EBR-II blanket fuel. Significant improvements to both cost and schedule are expected if a new technology can be brought to maturity by the AFCI program by 2013, whether it's an advanced pyroprocess or aqueous-based technology. The next section provides the technical details of some of the technologies being researched by the AFCI program that have potential applicability to EBR-II blanket fuel treatment.

4.0 Technological Descriptions for Alternative Blanket Fuel Treatments

The EBR-II blanket fuel was not subjected to the severe conditions the driver fuel encountered during the operation of the EBR-II. As a result, the sodium interaction with the blanket fuel rod allows for the potential of a physical or a combined physical/chemical removal of the sodium. Figure 4 shows the general diagram of an alternative treatment plan for the blanket fuel.

In the following sub-sections, technologies that address each of the potential steps will be discussed, including sodium removal, direct oxide conversion and aqueous processes. The aforementioned alternatives are not intended to be an inclusive list; however, these are currently believed to have the most promising prospects to reduce the costs and/or schedule for the EBR-II spent fuel treatment. At this time the Department recognizes that additional alternatives may be discovered or that a revision in the Spent Nuclear Fuel policy may occur during the EBR-II fuel treatment. In light of this realization, all due consideration will be given to the impacts and applicability of these alternatives as they come to light.

4.1 Metallic Fuel Pre-Treatment

If an alternative to pyroprocessing treatment is pursued, the first step of the alternative treatment process will be the physical removal of the sodium from the EBR-II fuel slug. Argonne National Laboratory has developed and demonstrated a technology called MEDEC (Melt Drain Evaporate Carbonate) that can safely accomplish the sodium removal. While the MEDEC technology has been demonstrated, a small research effort will still be required to statistically sample the EBR-II blanket fuel to determine the extent of any sodium incursion into the metallic fuel as well as characterizing the residual sodium that may remain after processing.

MEDEC Treatment for Sodium Removal

The MEDEC technology for removing metallic sodium from sodium-bonded spent nuclear fuel rods was developed and tested by ANL-W in the 1980s.[1] The basic concept behind MEDEC is to use a combination of heat and low atmospheric pressures to melt and vaporize the sodium away from the metal fuel. The entire process is undertaken within an argon atmosphere to prevent the reaction of sodium with oxygen in the atmosphere.

The first part of the MEDEC process consists of preparing the fuel by cutting off the ends of the fuel rods and insertion of pins to prevent the fuel slugs from falling out of the assembly. Following these preparation steps, the assemblies are heated to a temperature of 650 C under reduced pressure (200 milliTorr). After melting, the sodium will evaporate and later condense in a separate container, thereby removing the sodium from the fuel slug. Once the sodium has been successfully removed, the prepared assemblies will be chopped for future dissolution to prepare acceptable feed solutions for the aqueous-based or direct oxidation operations.

Sodium Melt Solvent Wash (SMSW) Treatment for Sodium Removal

While the MEDEC technology was originally developed to keep the fuel pins mostly intact, additional research could be undertaken to simplify the process since the EBR-II fuel will be separated from the cladding in order to be fed into the follow-on treatment processes, *e.g.* aqueous separations or direct oxide conversion. With the SMSW treatment process, the fuel slugs are removed from the cladding along with the melted sodium. After the melted sodium metal is physically separated from the fuel slug, any

[1] *MEDEC Treatment of FERMI-1 Sodium-Bonded Blanket Fuel in Preparation for Final Geologic Disposal A Life-Cycle Cost Estimate and Feasibility Report* A report prepared by Argonne National Laboratory for the Department of Energy, March 2003, F3640-1287-ES-00.

residual sodium remaining on the surface of the fuel will be removed by chemical reaction with a reactive alcohol or alcohol/water mixture.

The first part of the SMSW process is similar to that in the MEDEC treatment, preparing the fuel by cutting-off the ends of the fuel rods. In the SMSW process, the insertion of the pins to contain the fuel slugs is not required as the goal is to allow the entire slug and molten sodium to flow out of the cladding. Following the preparation step, the assemblies would be heated to a temperature of only 150 C (slightly above the melting point of sodium) and at atmospheric pressure. A special basket would need to be developed that would hold solid fuel slugs while allowing liquid sodium metal to pass. Once the bulk of the sodium has been successfully removed, the fuel slugs would be submerged in an inert solvent that contains either an alcohol, *e.g.* rubbing alcohol, or an alcohol/water mixture. The purpose of the solvent is to control the reaction rate and dissipate the heat from the exothermic reaction between the metallic sodium and the alcohol and/or water. Following sodium removal, the fuel slugs would be either converted into an oxide or dissolved to produce a feed for the aqueous-based processes discussed below.

4.2 Aqueous-based Uranium Separations

Within the AFCI program, research activities are currently underway to develop a variety of fuel separations technologies. The primary research efforts are focused in the areas of advanced pyroprocessing and aqueous-based processes. The aqueous-based processes currently under investigation are the ACP and UREX+ processes. The benefits of using these technologies to treat the EBR-II blanket fuel are detailed below.

<u>Actinide Crystallization Process (ACP)</u>

A program to develop ACP was initiated by the AFCI program in FY 2003. Based on a process originally developed by Germany and Japan, a majority of the uranium could be removed from dissolved spent fuel by a low temperature crystallization process. The process of crystallization leads to a decontamination of the uranium from the transuranics and fission products and with multiple passes could result in uranium classified as Class C low level waste. The ACP process is simple by design and is very compact, limiting the space and costs needed to build and operate the equipment.

The AFCI research is targeting recovery of uranium in the range of 90 to 95 percent with advances over the German and Japanese process in the way the solutions and crystals are handled. The work in this fiscal year has been focused on the fundamental underpinnings of the process and has been limited to depleted uranium and non-radioactive fission product surrogates. The experimental data for this process will be obtained from three distinct phases, bench-scale (10 grams) commencing in FY 2003, large laboratory-scale (3 to 10 kilograms) beginning in FY 2004, and demonstration-scale (> 50 kilograms) starting in FY 2005. If successful, this technology will be directly applicable to the EBR-II blanket fuel processing. The EBR-II spent fuel dissolved in nitric acid following the sodium removal process would be fed into crystallizers with a physical footprint similar to a refrigerator. The temperature of the solution would be lowered and the solution concentrated to form crystals of uranium. After washing, the crystals would be redissolved and run through the same process four to five times to reach the necessary decontamination factors needed for classification as low level waste. The remaining waste solutions would contain a small percentage of the uranium, plutonium, other transuranics, and fission products. These filtrates would go through denitrification and solidification steps to produce a high-level waste that could be converted into a form acceptable for disposal within a geologic repository. The development of this technology is in too early of a stage to estimate the potential annual throughput. However, rates in the area of five to ten metric tons per year appear technically feasible, resulting in a two to five year process time for the entire inventory of EBR-II blanket fuel.

Uranium Extraction Plus (UREX+)

The first step in the UREX+ process would be the treatment of spent fuel dissolved in nitric acid primarily with advanced liquid/liquid extraction techniques. Testing of the extraction equipment has shown that very high decontamination factors can be achieved through the UREX+ process.

The AFCI program is developing a plan to design and validate the UREX+ process shown in Figure 5. The throughput for a moderately-scaled UREX+ treatment facility can be very high, nearly an order of magnitude greater than the current pyroprocessing capacity. As a result, the remaining EBR-II blanket fuel could be processed in a UREX+ treatment facility in five years or less.

4.3 Direct Oxide Conversion

While not currently part of the Department's AFCI program, a small research effort could be pursued to investigate the direct conversion of the EBR-II blanket fuel from a metal form to an oxide form. The conversion of the EBR-II blanket fuel to an oxide fuel form would allow the material to be directly disposed of in a geologic repository.

5.0 Summary

The baseline plan for treating the EBR-II sodium bonded spent nuclear fuel is to use the pyroprocessing treatment technology. The initial emphasis will be on treating the 2.65 MTHM of highly-enriched EBR-II driver fuel. Treatment of the EBR-II driver fuel will be completed in Fiscal Year 2017. Treatment of the EBR-II blanket fuel will commence in Fiscal Year 2018 and be completed by 2030 with waste treatments finished in 2031. The schedule for completing the treatment of the EBR-II sodium-bonded spent nuclear fuel is provided in Figure 6. Summaries of the baseline pyroprocessing and potential alternative treatment technologies are provided in Table 2. The costs provided in Table 2 represent unescalated Fiscal Year 2003 dollars. Many of the cost savings are directly related to the reduced time required to process the nearly 20 MTHM of EBR-II blanket fuel. The costs for the MEDEC process have been well documented by Argonne National Laboratory. For the ACP and UREX+ process the development costs will be borne by the AFCI program as their direct application is to a larger-scale spent fuel treatment facility. The operational costs for the UREX+ process were developed during the preconceptual design of a moderately-scaled UREX+ experiment. The cost estimate for the SMSW, ACP and the direct oxide conversion were based on the fact that the facility or operational requirements for each of these processes are less than either MEDEC or UREX+.

The Department plans to take advantage of the research activities of the AFCI program to improve both the schedule and costs for treating the EBR-II blanket fuel. The potential schedule benefits which could arise from the application of AFCI-developed fuel treatment technologies to the EBR-II blanket fuel are also illustrated in Figure 6. The Department expects to make a decision in the 2013 timeframe on the potential application of AFCI-developed treatment technologies beginning in 2017.

The Department remains committed to meeting the 2035 deadline for removal of all spent nuclear fuel, including the EBR-II sodium-bonded spent nuclear fuel from the Idaho Site which is the focus of this report.

Figure 1. Sodium-Bonded Nuclear Fuel Element

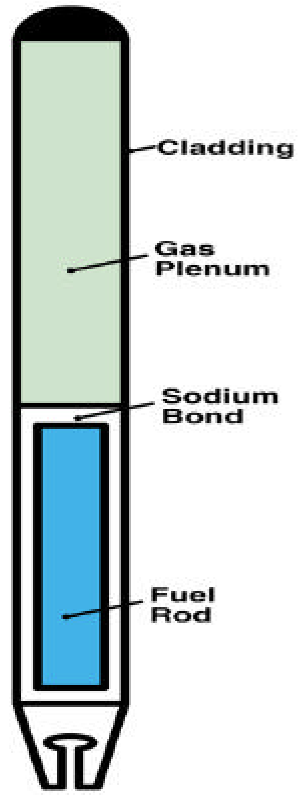

Figure 2. The Pyroprocess Flowsheet

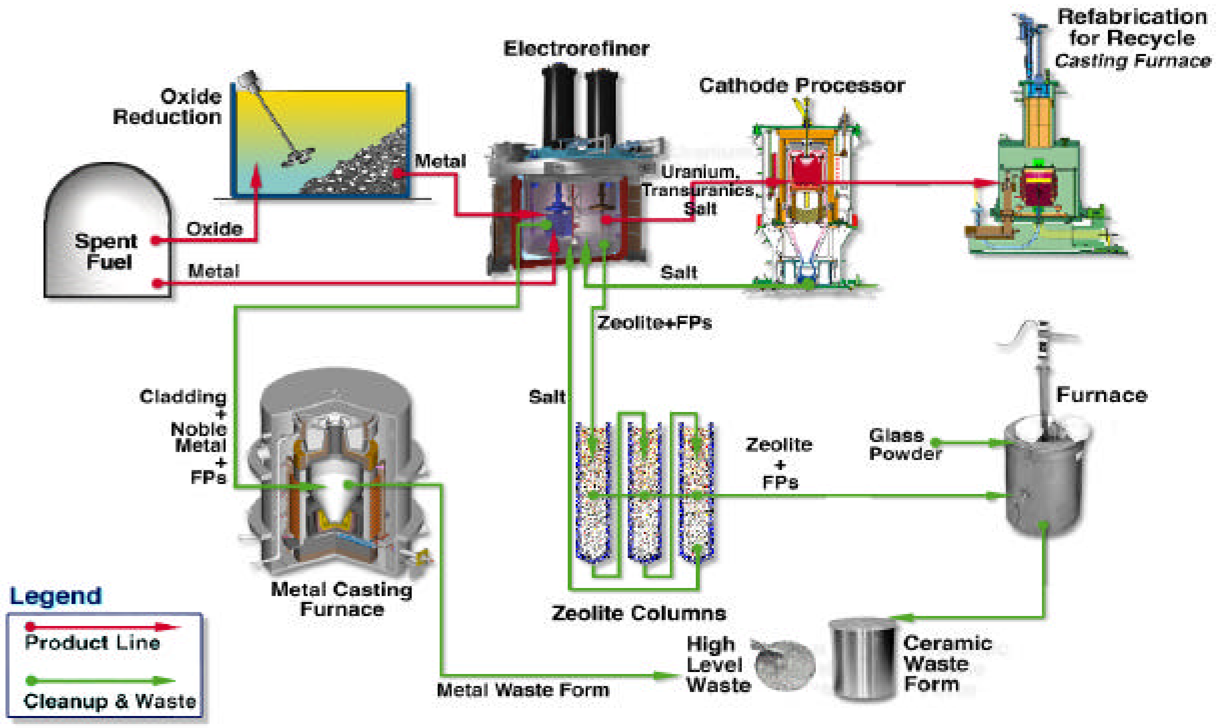

Figure 3. Amount of Untreated EBR-II Blanket and Driver Fuel and Pyroprocessing Fuel Treatment Costs as a Function of Time for the Baseline SFT Plan.

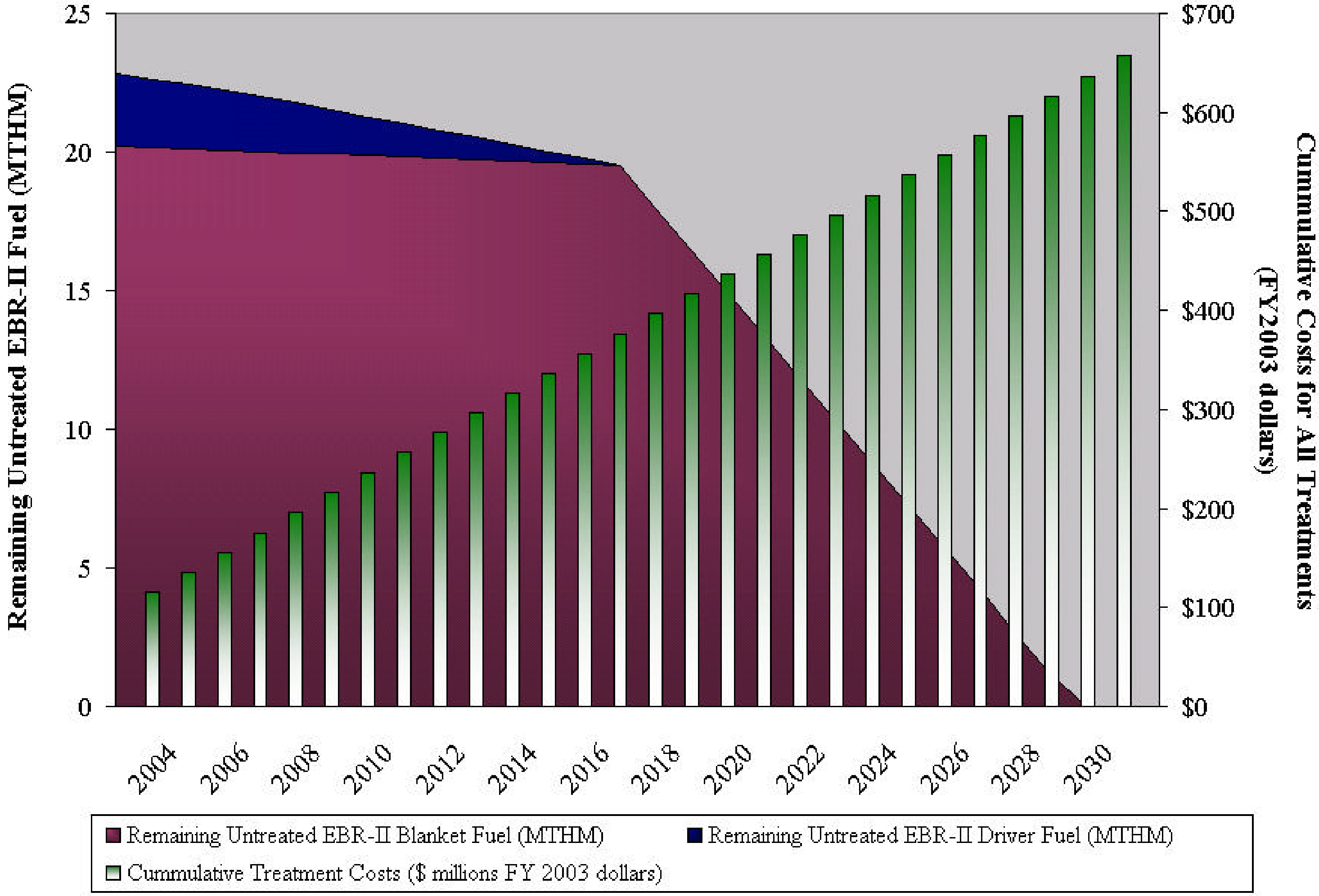

Figure 4. Diagram of Potential Alternative Blanket Fuel Treatments

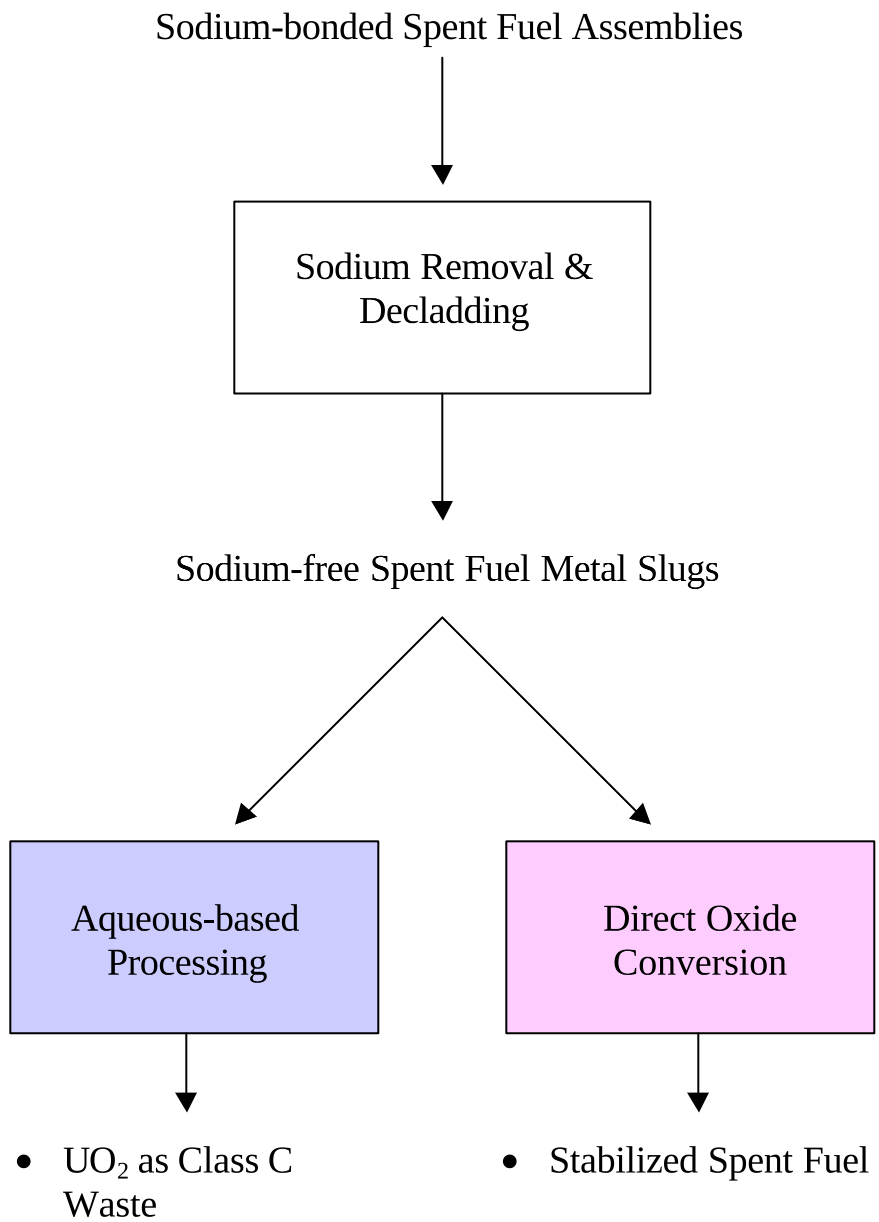

Figure 5. The UREX+ Flowsheet

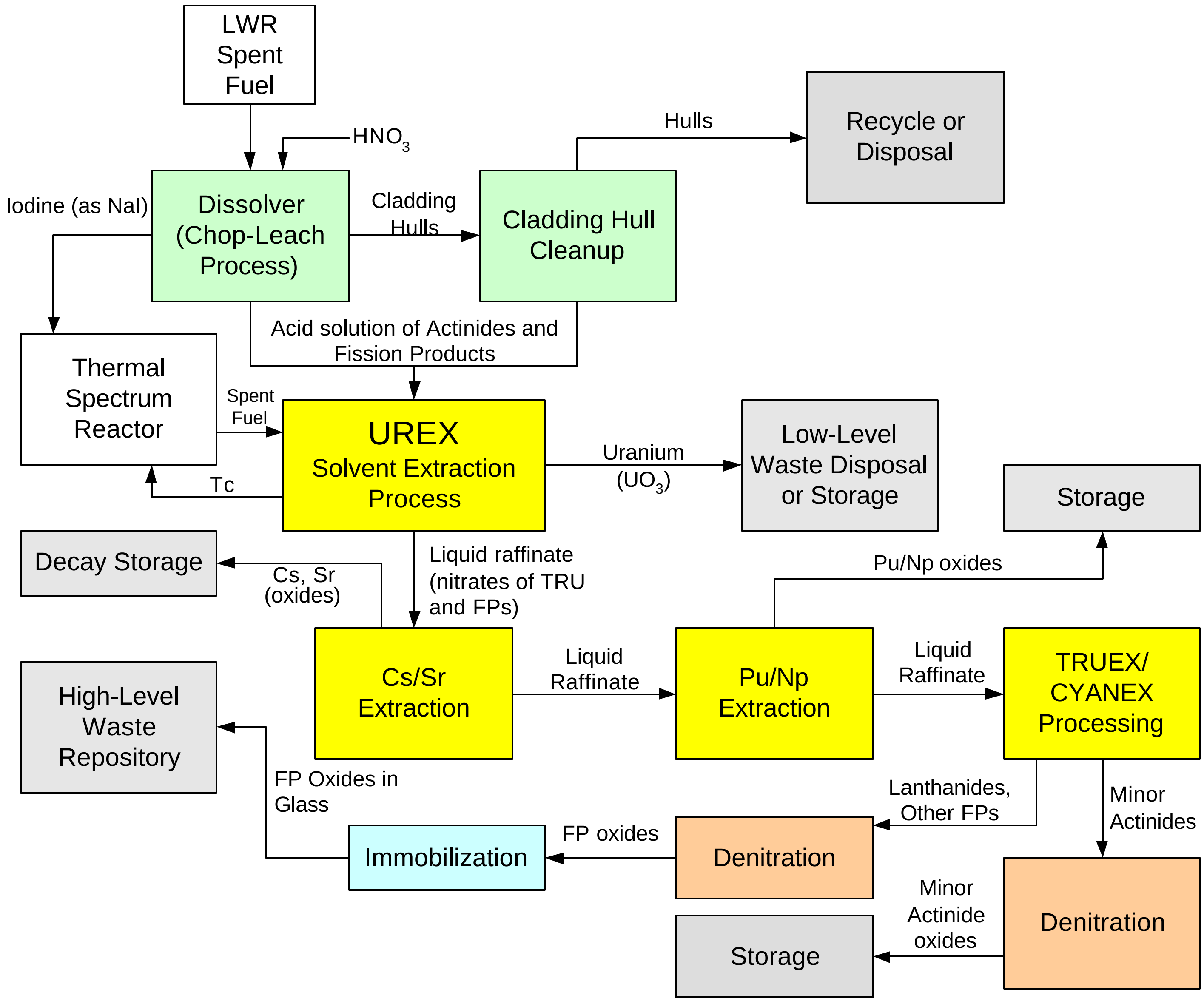

Figure 6. Schedule for Baseline and Alternative Treatment Plan for EBR-II Sodium-Bonded Spent Nuclear Fuel

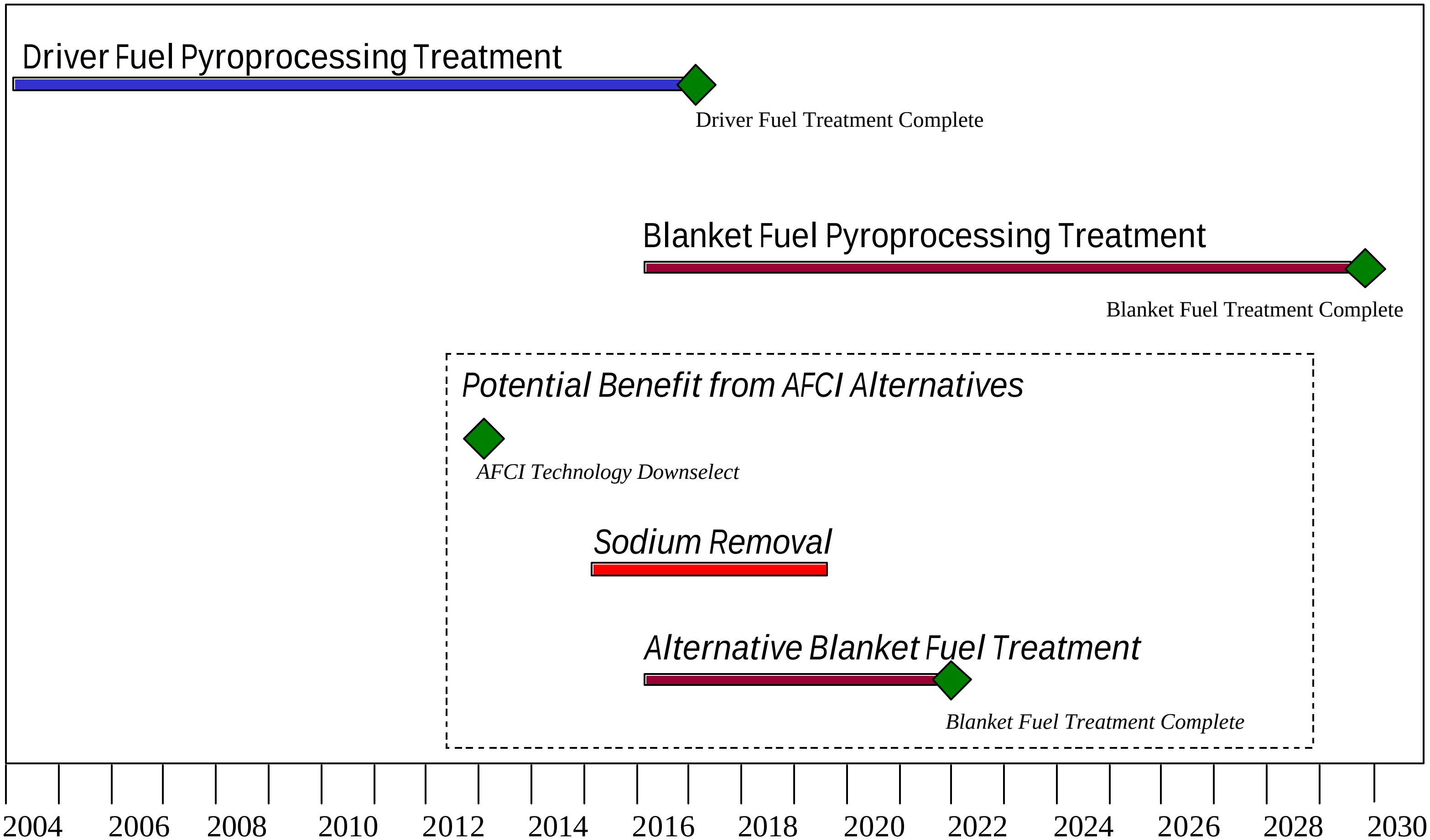

Table 1. Summary of the Quantities of Sodium-bonded EBR-II Spent Nuclear Fuel

	Initial Inventory		**Treated by Pyroprocessing***		**Remaining Untreated**	
Fuel Type	Weight (MTHM)	Number of Assemblies	Weight (MTHM)	Number of Assemblies	Weight (MTHM)	Number of Assemblies
Driver	3.10	760	0.45	110	2.65	650
Blanket	22.42	480	2.20	50	20.22	430
Total	25.52	1240	2.76	160	22.87	1080

* Through the middle of Fiscal Year 2003

Table 2. Summary of Technologies Applicable to EBR-II Blanket Fuel Treatment

	Demonstrated Technologies		Research and Demonstration Technologies			
Technology	Pyrochemistry	MEDEC	SMSW	ACP*	UREX+*	Direct Oxide Conversion*
Accomplishes	chemical sodium removal; uranium separations	physical sodium removal	decladding and physical sodium removal	uranium separations and stabilization	uranium separations and stabilization	uranium stabilization
Time Required for Treatment**	10 – 15 years	5 – 6 years	3 – 5 years	3 – 4 years	4 – 5 years	3 – 5 years
Radioactive Products	uranium metal ingot; ceramic HLW	uranium metal spent fuel slug in assembly	decladded uranium metal spent fuel slug	UO_2 Class C waste; solid HLW waste form	UO_2 Class C waste; solid HLW waste form	HLW in form of spent fuel oxide
Technical Benefit	baseline technology	baseline technology	less extreme operating conditions	reduction of amount of HLW and TRU waste	reduction of amount of HLW and TRU waste	reduction in handling time
Estimated Cost***	$260 M	$60 - 75 M	<$60 M	<$45 M	$45 M	<$45 M

***** Requires physical removal of sodium before process is begun.
** Time required to process 20.22 MTHM of EBR-II Blanket Fuel with the particular technology
*** Costs given in unescalated Fiscal Year 2003 dollars